CHAPTER XIII

EMERY MINE FEDERAL LEASE INCIDENTAL BOUNDARY CHANGE APPLICATION

EMERY MINE
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EMERY COUNTY, UTAH

SUBMITTED TO

UTAH DIVISION OF OIL, GAS AND MINING

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CHAPTER XIII

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XIII.A INTRODUCTION

This application for an incidental boundary change ("IBC") is submitted to the Utah Division of Oil, Gas and Mining ("UDOGM") by Consolidation Coal Company ("Consol") for the Emery Mine in Emery County Utah (UDOGM Permit No. ACT/015/015). The IBC area encompasses approximately 160 acres of private land and Federal coal adjacent to the northeast portion of the existing Emery Mine permit area (see Plate I-1 of the approved MRP). The IBC falls within the area of an existing Cumulative Hydrologic Impact Assessment and is within a drainage basin already authorized in the approved mining and reclamation plan ("MRP").

Approval of this IBC request will allow Consol to develop additional coal reserves in the northern portion of the permit area without the need for new surface disturbances. Coal will be extracted under this application from the IJ zone of the Ferron Sandstone using room and pillar methods with~~out~~ pillar extraction ~~(i.e., first mining only)~~ (i.e. planned subsidence).

XIII.B GENERAL CONTENTS

XIII.B.1 RIGHT OF ENTRY

The U.S. Government is the owner and Consol is the leaseholder (Lease No. U-50044) of all coal to be mined under this IBC application (see Plate I-1 of the approved MRP). Information regarding coal ownership within the IBC and adjacent areas is provided in Chapter I of the approved MRP.

All of the Federal Lease IBC surface land is owned by D.U. Company Inc. (see Plate I-1). Information regarding surface ownership within the IBC and adjacent areas is provided in Chapter I of the approved MRP. Consol knows of no pending litigation concerning their right to mine coal within the IBC area.

XIII.B.2 LEGAL DESCRIPTION AND STATUS OF UNSUITABILITY CLAIMS

The area affected by this IBC application is located in SW¼NW¼, NW¼SW¼, NE¼SW¼, and SE¼SW¼ of Section 22, T. 22 S., R. 6 E., SLBM. Consol knows of no portion of the Federal Lease IBC that is designated, or under study to be designated, as unsuitable for mining. Consol does not propose to conduct coal mining or reclamation operations in the IBC area within 300 feet of any occupied dwelling or within 100 feet of a public road.

XIII.C ENVIRONMENTAL RESOURCE INFORMATION

XIII.C.1 PERMIT AREA

The lands subject to coal mining operations within the IBC area are noted on Plate I-1. It is not anticipated that individual permits will be sought for subareas within the IBC area. A discussion of cultural resources within the IBC area is provided in Appendix XII-3 of the approved MRP. This prior Class I survey, conducted in May 2005, included all of the area of the Federal Lease IBC and identified no cultural resources within that area.

XIII.C.2 SOIL RESOURCE INFORMATION

Soil resources in the IBC area are depicted in Figure XIII-1. Descriptions of these soils are provided in Appendix XIII-1. Soil series descriptions in the appendix were obtained from the U.S. Natural Resources Conservation Service (2006). Descriptions of individual map units were obtained from Swenson et al. (1970). Soils within the IBC area tend to be fine grained, ranging generally from loam to silty clay loam. If irrigated, the soil supports alfalfa and similar crops. Otherwise, the soils mostly support rangeland plants such as shadscale, Indian ricegrass, greasewood, and/or saltgrass. Penoyer Loam and Ravola Loam are considered prime farmland when irrigated (Appendix XIII-1). About 2 acres of Penoyer Loam and 10 acres of Ravola Loam are irrigated and, therefore, may be prime farmland within the IBC area. ~~Although~~ ~~s~~Subsidence-related ~~is not planned,~~ ground movement will be monitored in accordance with Section V.B.1 of the MRP.

Additional information regarding soil resources in the IBC and adjacent areas is provided in Chapter VII of the approved MRP. Impacts to soil resources are not anticipated as a result of mining under this application since no new surface disturbances are planned.

XIII.C.3 VEGETATION RESOURCE INFORMATION

Information concerning vegetation resources within the IBC area is provided in Appendix XIII-2. Three plant communities are present in the IBC area, namely greasewood, shadscale/winterfat, and pasture (both irrigated and dry land). Information presented in Appendix XIII-2 indicates that federally-listed threatened or endangered plant species are not likely to exist in the IBC area. No impacts to vegetation are anticipated from mining in the IBC area due to the planned non-disturbance of the surface.

XIII.C.4 FISH AND WILDLIFE RESOURCE INFORMATION

Information regarding fish and wildlife resources within the IBC and adjacent areas is provided in Appendix XIII-2. Additional information regarding fish and wildlife resources in the IBC and adjacent areas is provided in Chapter IX of the approved MRP. The IBC area is located within a zone of high value winter habitat for elk.

It is unlikely that raptors occur within the IBC area. One prairie dog community is located with the IBC area (see Chapter IX of the approved MRP). Given the lack of ~~planned subsidence~~new surface disturbances, it is not anticipated that impacts will occur to these or other wildlife resources from coal mining in the IBC area. Although several Federally-listed threatened or endangered animal species are known to occur in Emery County, a lack of appropriate habitat greatly reduces the potential for any of these species to occur within the IBC area (see Appendix XIII-2).

XIII.C.5 GEOLOGIC RESOURCE INFORMATION

Information regarding geologic resources within the IBC and adjacent areas is provided in Chapter V of the approved MRP. The Bluegate Shale member of the Mancos Shale outcrops over the entire surface of the IBC area. This unit is a saline, blue-gray silty mudstone and siltstone with occasional, thin sandstone lenses. The Bluegate Shale abruptly overlies the Ferron Sandstone member of the Mancos Shale. The Ferron Sandstone consists of interbedded layers of sandstone, siltstone, shale, and coal, with the coal to be mined in the IBC area occurring in the upper portion of the Ferron Sandstone in a layer known as the IJ zone. The Tununk Shale member of the Mancos Shale underlies the Ferron Sandstone.

Based on data provided on Plate V-20 of the approved MRP, approximately 300 to 500 feet of overburden overlies the IJ zone within the IBC area. Roof and floor materials above and below the IJ zone within the IBC area are expected to be as indicated in Section V.A.4 of the approved MRP, consisting of interbedded sandstone and shale. Dark gray shale typically contacts the roof of the coal, with several feet of irregularly laminated, light gray, fine-grained quartz sandstone above the shale. The floor material is generally dark olive gray, coaly, silty shale interbedded with light gray, fine grained quartz sandstone.

According to Section V.A.4 of the approved MRP, the pH of the roof material ranges from about 5 to 9, with the pH of the floor materials tending to be slightly higher. The roof and floor materials tend to have low salinity (specific conductance less than 4.0 mmhos/cm), with moderate to high sodium adsorption ratios (1.8 to 28) and concentrations of heavy metals that are sufficiently low to not influence reclamation decisions.

The coal, overburden, and underburden in the IBC area are unlikely to have substantial acid-forming potential, as indicated by the pH of the rock and the slightly alkaline nature of water that has historically discharged from the Emery Mine (pH 7.1 to 8.5 – see Section V.A.5 of the approved MRP). Furthermore, as indicated in Section V.A.6 of the approved MRP, the sulfur content of the coal is generally low (typically 0.5 to 2.0 percent, with an average of about 0.7 percent), with variable proportions of the sulfur existing as pyrite. Concentrations of toxic constituents in the coal, overburden, and underburden are low (see Section V.A.4 of the approved MRP).

A comparison of Plates V-20 and VI-4 of the approved MRP indicates that the complete thickness of the Ferron Sandstone is probably saturated within the IBC area. Additional information regarding groundwater within the IBC and adjacent areas is provided below and in Chapter VI of the approved MRP.

XIII.C.6 HYDROLOGIC RESOURCE INFORMATION

XIII.C.6.1 Baseline Information

Mining within the IBC area will not involve the construction of additional surface facilities. ~~Furthermore, as indicated in Section XIII.A, coal will be mined under this application using room and pillar methods without pillar extraction (i.e., first mining only).~~ Hence, no surface disturbance is planned.

Baseline hydrologic data have been collected from several surface and groundwater monitoring locations adjacent to the IBC area (see Plates VI-1 and VI-3 of the approved MRP). These data are discussed in Chapter VI of the approved MRP. Given the lack of surface disturbance planned for the IBC area and the close location of the IBC area relative to the existing permit area, the existing baseline data are considered adequate for the IBC area.

XIII.C.6.2 Groundwater Information

As indicated in Chapter VI of the approved MRP, the complete thickness of the Ferron Sandstone is probably saturated within the IBC area, normally under confined conditions. Although the formation dips to the northwest (see, for instance Plate V-20), groundwater flows generally to the south or southeast (see Plates VI-5 and VI-9 as well as Figure XIII-2) except where influenced by mining in the area (Plate VI-4). The hydrostatic pressure required to force groundwater up dip in the mine area is generally believed to originate from recharge along the Joe's Valley-Paradise fault zone located at higher elevations north and west of the mine area.

Although the Ferron Sandstone is completely saturated within the existing mine area, historic inflows to the mine have been predominantly from the roof rather than the floor. This suggests that the upper and lower portions of the Ferron Sandstone are hydraulically separated. This hydraulic separation is also suggested by a comparison of Plates VI-4 and VI-5 of the approved MRP, which indicates that past impacts of mining on the potentiometric surface of the area have occurred primarily in the upper Ferron Sandstone, with no noticeable potentiometric-surface impacts in the lower Ferron Sandstone.

Groundwater discharges from the Ferron Sandstone by wells, by dewatering of the Emery Mine, by seepage into Quitchupah Creek and Christiansen Wash, and by leakage into the Bluegate and Tununk Shales. Within the immediate vicinity of the IBC area, the largest anthropogenic discharge of groundwater from the Ferron Sandstone is dewatering of the Emery Mine which, according to Chapter VI of the approved MRP, accounts for approximately 0.6 to 1.2 cubic feet per second of water being removed from the Ferron Sandstone.

Natural groundwater quality in the *upper* Ferron Sandstone is moderately saline, with total dissolved solids concentrations in monitoring well and mine roof inflow samples averaging approximately 1000 to 1300 mg/l (see Table VI-9 of the approved MRP). The total dissolved

Water in the Emery Mine comes into contact with rock dust, thereby increasing the total dissolved solids concentration of this water prior to being pumped to the surface into Quitchupah Creek. Similar impacts are anticipated from mining in the IBC area. According to Section VI.A.7 of the approved MRP, the salt load of Muddy Creek (into which Quitchupah Creek eventually discharges) is expected to increase 10 to 17 percent as a result of mining in the Emery Mine. The salt load of the Dirty Devil River (into which Muddy Creek discharges) has historically increased less than 1 percent due to mine-water discharges. Assuming the total dissolved solids concentration of water discharging from the IBC area is similar to that in the remainder of the Emery Mine, and assuming that mining in the IBC area results in an increase in the mine-water discharge to Quitchupah Creek of 5 percent, the total salt load of Muddy Creek will increase 1 to 2 percent due to mining in the IBC area. No water rights exist downstream of the mine discharge point on Quitchupah Creek or Ivie Creek (the receiving stream for Quitchupah Creek). Hence, no substantially increased impacts to water users are anticipated from salt loading due to mining in the IBC area.

No additional surface area will be disturbed under this application. Hence, additional sediment loads to local streams will not occur.

XIII.D OPERATION PLAN

XIII.D.1 MINING OPERATIONS AND FACILITIES

Coal will be extracted under this application using room and pillar methods with~~out~~ pillar extraction ~~(i.e., first mining only)~~ (planned subsidence). It is anticipated that approximately ~~900,000~~1.27 million tons of coal will be mined from the IBC area. Mining will occur using a continuous miner. General criteria for pillar design are provided in Section V.B.1 of the approved MRP.

No new surface facilities will be constructed under this application. Facilities associated with the Emery Mine that will be used during mining of the IBC area are discussed in Chapter II of the approved MRP.

The anticipated sequence of mining in the IBC area is indicated on Plate IV-2. This map also shows existing and anticipated underground workings within the current permit area and, for completeness only, potential mine workings outside of both the current permit area and the Federal Lease IBC area. Coal will not be extracted from areas outside the current permit area or the Federal Lease IBC area until those areas are properly permitted.

~~Although no subsidence is planned under this application,~~ Plate V-5 shows locations of proposed subsidence monitoring stations in the IBC and adjacent areas. These stations will be established as indicated in Figure V-8 of the approved MRP. These stations will be monitored as outlined in Section V.B.1 of the approved MRP.

XIII.D.2 EXISTING STRUCTURES

No "existing structures", as defined in R645-100-200, exist in the IBC area. Structures located in other portions of the permit area that will be used during mining of the IBC area are discussed in Chapter II of the approved MRP. These structures will not be modified under this application.

XIII.D.3 COAL RECOVERY

Coal will be recovered in a manner that maximizes utilization and recovery of the resource, (planned subsidence), while maintaining environmental integrity. ~~This plan will be modified if future designs call for extraction of the pillars.~~

XIII.D.4 SUBSIDENCE CONTROL PLAN

~~No s~~Subsidence ~~is planned for~~control, monitoring, and mitigation within the IBC area will occur as indicated in Section V.B of the approved MRP.

XIII.D.5 HYDROLOGIC INFORMATION

Information regarding surface and groundwater resources and probable hydrologic impacts of mining in the Federal Lease IBC and adjacent areas is provided in Section XIII.C.6 of this application. A discussion of surface and groundwater monitoring programs associated with the Emery Mine is provided in Section VI.A.5 of the approved MRP. Information regarding the acid- and toxic-forming potential of the coal, overburden, and underburden is discussed in Section XIII.C.5 of this application.

No surface disturbances are planned in the IBC area. Hence, no new diversions, stream buffer zones, sediment control structures, or other treatment facilities will be installed as a result of mining in the Federal Lease IBC area.

XIII.E RECLAMATION PLAN

No new surface disturbances will occur as a result of mining in the Federal Lease IBC area. Hence, no additional land reclamation will be required as a result of this action. Information regarding reclamation of the Emery Mine surface facilities is provided in Chapter III of the approved MRP. This information includes a discussion of surface and groundwater monitoring programs, structure removal, backfilling and grading operations, drainage control, topsoil redistribution, site revegetation, etc.

XIII.F CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT

The Federal Lease IBC area lies within the existing cumulative hydrologic impact assessment ("CHIA") area associated with the Emery Mine. The CHIA that was previously prepared in conjunction with permitting the Emery Mine should be sufficient for evaluating the hydrologic impacts of the Federal Lease IBC area.

Development of the mine is accomplished with seven or eight entry mains with entries on 80 foot centers and crosscuts on 100 foot centers. The submains for panel development typically use a five entry system with similar entry centers. Panels are developed off the mains or submains with a four or five entry system with rooms driven on either side of the development entries. The Emery Mine ~~does not~~ uses a ~~maximum~~ partial extraction technique~~s, but instead uses a system of partial~~during secondary extraction (unplanned subsidence), which leaves the roof intact (see Chapter V Part B), ~~(~~except in areas designated as full extraction (planned subsidence) as depicted on Plate V-5~~the First South panel where full extraction will occur) which leaves the roof intact (see Chapter V Part B)~~.

During the term of this permit the planned production for the Emery Mine is 1.7 million tons per year. The mine will produce this coal with five continuous miner sections. Producing at this rate, the mine will continue operations until 2010 at which time the IJ Zone will be mined out. At that time final reclamation will begin as discussed in Chapter III.

4 EAST PORTAL

Site Description

The site is entirely within the surface area owned by Consolidation Coal Company. Coal ownership is also in Consolidation Coal Company's name.

Geology:

Drill hole FC 702, located on the site, was cored from the surface to below the IJ seam. It provides a detailed stratigraphic sequence and geochemical analyses to characterize the overburden to be stockpiled on the site. The following three pages show the lithology of the overburden and contain the geochemical test results on strata intervals. The portal excavation does not go any deeper than the top eleven (11) feet of the IJ seam.

Acid-Forming Potential:

Sulphur values (PS, SO4S, OS, and TS) are low throughout the strata. Moreover, pyritic sulphur, a potential acid former, is present in very low concentrations (less than 0.01 percent), so the acid-forming potential is quite small. As a result, acid production is not anticipated to be a problem within the proposed construction area.

Alkalinity-Forming Potential:

High pH and/or high SAR can cause piping, surface crusting, soil structure problems, and plant toxicities. The only samples with alkaline pH (8.1-8.3) occurred below the coal seams. Likewise the floor strata samples tested distinctly more sodic than the overburden. Since the excavation does not go this deep, alkaline material production is not anticipated.

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Revised12/06

IV.A.3 MAXIMUM ECONOMIC RECOVERY

UMC 784.13(b)(6), 817.59

The mining operation at the Emery Mine maximizes the recovery of the IJ Zone while maintaining safety as a primary priority. The following criteria are used to determine the mineability of the coal:

1. The minimum required mining height is 5 feet.

2. Two feet of combined roof and floor coal is left. The shale under the coal has a high clay content making it susceptible to water requiring a minimum 1.5 feet of floor coal to be left in place to prevent floor heaving. In areas of shale top, top coal must be left to maintain roof stability.

3. The maximum mining height will be 10 feet from a safety standpoint to provide stable coal pillars (see Chapter V Part B).

The Emery Mine uses a partial extraction technique (unplanned subsidence) to maintain a stable top during secondary mining, except in areas designated as full extraction (planned subsidence) as depicted on Plate V-5.~~the First South panel, to maintain a stable top.~~ Partial and full pillar extraction plans for the mine are described in Chapter V, Section V.B.1. In those areas where protection must be given to prevent subsidence (see Chapter V Part B), no secondary mining will take place. By leaving larger pillars in these areas the surface should remain unaffected.

There are no coal seams above the IJ Zone that are considered mineable under the above mentioned criteria. Any future operations will take place in coal seams below the IJ Zone and will not be adversely affected by current mining operations in the IJ Zone.

Additional information related to recoverability of the other coal seams is in Appendix IV-I. This appendix deals with the maximum economic recovery of the coal in Federal Lease U-5287.

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The mining method used in most of the mine is room and pillar with partial pillar removal. Full extraction mining (planned subsidence) is proposed at Emery ~~only in the First South panel,~~ in areas designated as full extraction as noted on Plate V-5. As a result, any subsidence outside of ~~the First South panel~~ these areas would fall into the unplanned category. Figure 1 pg. 28 shows the partial pillar splitting diagram employed underground. This layout is the result of past experience as well as state and federal regulations pertaining to roof control and ventilation. All pillar splitting will be approved by MSHA. A pillar split diagram specific to full extraction is provided in Figure 2 (page 29).

Consol intends to prevent subsidence from affecting Quitchupah Creek, Christiansen Wash and the alluvial valley floor area on the west side of the permit area (Refer to Plate V-5). There will be no full extraction within the designated buffer zones. An intermittently occupied dwelling in Section 30 will also be protected from subsidence. As of the date of this writing, a subsidence waiver has not been obtained on this dwelling. At such time as a waiver is obtained, the Division shall be notified and the buffer around this dwelling will be removed. Other than these features, the presubsidence survey, and our knowledge of the permit area confirms that there aren't any structures overlying present or future underground workings for which mitigation of subsidence effects would be overly difficult.

The three above noted features will be protected by establishing buffer zones which in turn are created by leaving coal pillars of adequate size beneath these areas. The dimensions of the buffer zone will be determined by the overburden depth and the angle of draw. With respect to Quitchupah Creek and Christiansen Wash, the buffer zone will include an additional standoff distance of 100 ft. on either side, as required by UMC 817.57. The pillar dimensions are based on established geotechnical information and a factor of safety for long term pillar stability. The partial pillar splitting design data can be found at CH V Page 28a, 28b, and 28c. A pillar split plan sketch can be found at CH V Page 28 and Figure V-1 on CH V Page 28d. As can be seen from the following design data this partial pillar splitting plan will not result in subsidence, and is considered unplanned subsidence per the MRP.

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CHAPTER VI

HYDROLOGY

APPENDICES

Revised 12/06

CHAPTER VI – HYDROLOGY

PLATES (In Map Pockets)

Revised 12/06

VI.A.7 DETERMINATION OF PROBABLE HYDROLOGIC CONSEQUENCES

UMC 784.14(c)

The surface and ground water hydrology in the vicinity of the Emery Mine is complex due in part to the imperfect understanding of the communication of ground waters within the various stratigraphic units above and below the mine and due to the unpredictable man-caused variation in streamflow and water quality, resulting from irrigation practices. Isolating the effects of mining on the surface and ground water systems is somewhat difficult but there are several influences which can be distinguished:

1. Temporary creation of mineward gradients induced by mine water inflow affecting ground water declines.

2. Changes in surface water quality and quantity due to discharge of intercepted water by the mine.

Hydrogeologic Setting

As noted previously in this chapter, the coal at the Emery Mine occurs in the Ferron Sandstone Member of the Mancos Shale. For the purposes of this document, the Ferron Sandstone Member has been divided into three units (see Section VI.A.2): the upper Ferron Sandstone, Kmf(u); the middle Ferron Sandstone, Kmf(m); and the lower Ferron Sandstone, Kmf(l). In the upper Ferron, sandstones are lenticular, channel-shaped bodies that are generally less than 40 feet thick. These channel sandstones are characterized by unidirectional cross-stratification, fining-upward cycles, and lateral interfingering with mudstones. The middle and lower Ferron consists of thin-bedded sandstone and shale at the base that grade upward to thick, cliff-forming sandstones.

The Ferron Sandstone lies between and intertongues with marine shales in the Tununk and Blue Gate Members of the Mancos Shale. The Blue Gate Member unconformably overlies the Ferron and is composed primarily of gray bentonitic, calcareous shale. The Tununk Member is lithologically similar to the Blue Gate Member.

The Ferron Sandstone outcrops in a series of prominent cliffs along the eastern edge of the Emery coal field and dips 2 to 10° to the northwest beneath the land surface. The continuity of the Ferron is broken in the subsurface by the Joes Valley-Paradise fault zone, which exists immediately northwest of the permit area. This fault zone extends for about 60 miles northeast and 20 miles southwest of the mine area[1].

A comparison of Plate VI-4 with Plates V-19 through V-22 indicates that the Emery Mine usually operates within the saturated zone, except along the outcrop to the east and where water levels have been locally altered due to mining activities. Morrissey et al. (1980) indicate that recharge to the Ferron aquifer originates in the Wasatch Plateau west of the Emery Mine and discharges to the southeast along the Joes Valley-Paradise fault zone (see also page 57 of this chapter). Hence, this fault zone acts as a linear source of groundwater recharge to the Ferron Sandstone. The contribution of precipitation to direct recharge of the Ferron Sandstone overlying the mine is probably small, since precipitation in this area is low (averaging about 8 inches annually above the Emery Mine) and the area is overlain by the relatively impermeable Blue Gate Member of

[1] Hintze, L.F. 1980. Geologic Map of Utah. Utah Geological and Mineral Survey. Salt Lake City, Utah.

the Mancos Shale. Currently, water is discharged from the Ferron aquifer in the region by mining operations, wells, leakage along streams, and springs.

Mining within the Emery Mine has locally changed the pattern of ground water flow near the mine, and part of the upper section of the Ferron Sandstone aquifer has experienced water-level declines (see Plate VI-4). As mining has progressed, the mine has intercepted more and more ground water and caused a cone of depression near the northwest corner of mined area.

Groundwater ~~Declines~~Discharge from Mining Operations

Of significance to the groundwater hydrologic balance is the potential for water level declines in the Ferron Sandstone aquifer resulting from mining. Groundwater has the potential to enter the Emery Mine through both the floor and roof of the mine workings from permeable, saturated sandstones above and below the IJ coal seam. Static water level hydrographs for monitoring wells found in Figures VI-6 through VI-9 show that water level declines have been experienced in all three sections of the Ferron aquifer and also in the Blue Gate shale. The hydrographs indicate that the primary source of inflow to the mine is from the upper Ferron aquifer - Kmf(u) and to a lesser degree the middle Ferron - Kmf(m). Significant upward leakage from the Kmf(m) is impeded by underclays which constitute the floor of the mine.

As reported by Owili-Eger (1979) upward leakage in the form of a spring has occurred at only one location in the mine.

Alteration of the flow pattern within the Ferron Sandstone aquifer is caused by the creation of mineward gradients induced by inflow of water to the mine. These conditions in turn affect groundwater level declines in the mined area and in the surrounding area. Since the principal avenue of inflow to the mine is through the roof of the workings, the upper portion of the aquifer is most subject to water level declines.

Average inflow to the Emery Mine during the period of 1979 through 2005 is shown in Figure VI-20A (see also Appendix VI-9). No data are available for the years prior to 1979. Discharge from the mine continued through a period of temporary shutdown (1991 through 2001). Although coal was not being mined during this period, Consol continued to pump water to maintain the mine in an accessible condition.

A mass balance approach was used to predict future groundwater discharge rates from the mine. The water balance equation used for this analysis is:

Inflow = Outflow + Change in storage

Given the probable lack of substantial direct recharge from precipitation to the Ferron Sandstone in the mine area, inflow to the mine occurs predominantly from groundwater that flows toward the mine from the Joes Valley-Paradise fault zone into the Ferron Sandstone. Outflow occurs when groundwater is either pumped from the mine or used underground for various purposes (i.e., dust suppression, equipment cooling, etc.) and then removed from the mine as moisture in the coal or in the mine air.

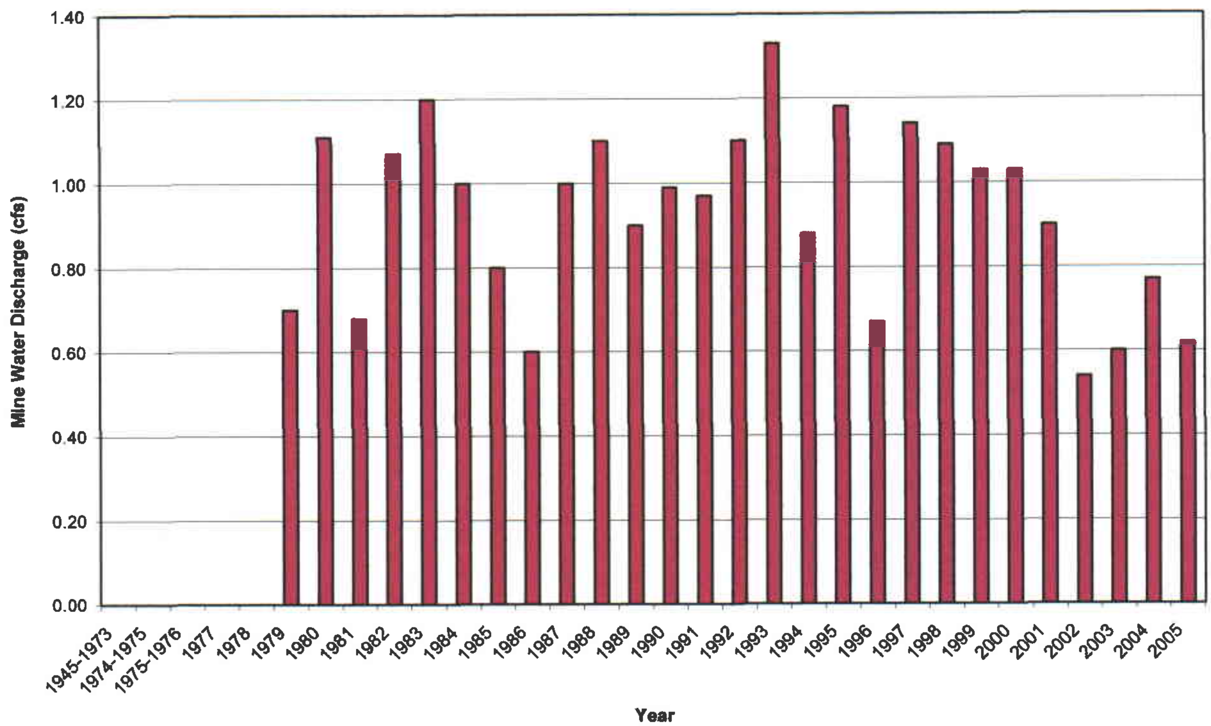


Figure VI-20A. Average Mine Water Discharge By Year

Groundwater inflow to the mine occurs either horizontally (due to the mine being within the flow path) or vertically (due to gravity drainage from the overlying sandstone into the mine void). In a study by the U.S. Geological Survey of the Emery Mine area, Lines (1987)[2] found that "prior to mining, the vertical component of flow was upward from the Ferron into the Blue Gate Member. As mining progressed, ground-water flow was directed toward the mine workings, and much of the aquifer and other rocks above the mined coal bed were dewatered. The steady-state pattern of [predominantly horizontal] flow . . . probably would not develop unless mining ceased and dewatering of the mine continued for several years." These conditions are depicted on Figure VI-20B.

For the sake of this analysis, it was assumed that the steady state condition identified in Figure VI-20B(c) was reached during the several-year shutdown period of 1991 through 2001. Under this condition and assuming no substantial change in underground water storage during the shutdown, water discharged from the mine during this period would equal the amount of predominantly horizontal inflow to the mine. Data contained in Appendix VI-9 indicate that discharge from (and therefore horizontal inflow to) the mine during the shutdown period averaged 1.03 cfs. The length of mine exposed to the groundwater flow path during this period was 2.17 miles (see Plate VI-6A). Hence, the ratio of horizontal inflow per unit length of mine exposed to the groundwater flow path is 0.47 cfs/mi.

[2] Lines, G.C. 1987. Ground-Water Study 11. pp. 365-396 *in* Ground-Water Information Manual: Coal Mine Permit Applications – Volume II. U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement. Available online at http://www.ott.wrcc.osmre.gov/library/hbmanual/grdh20info/OSM-GWInfoManual-II-11.pdf

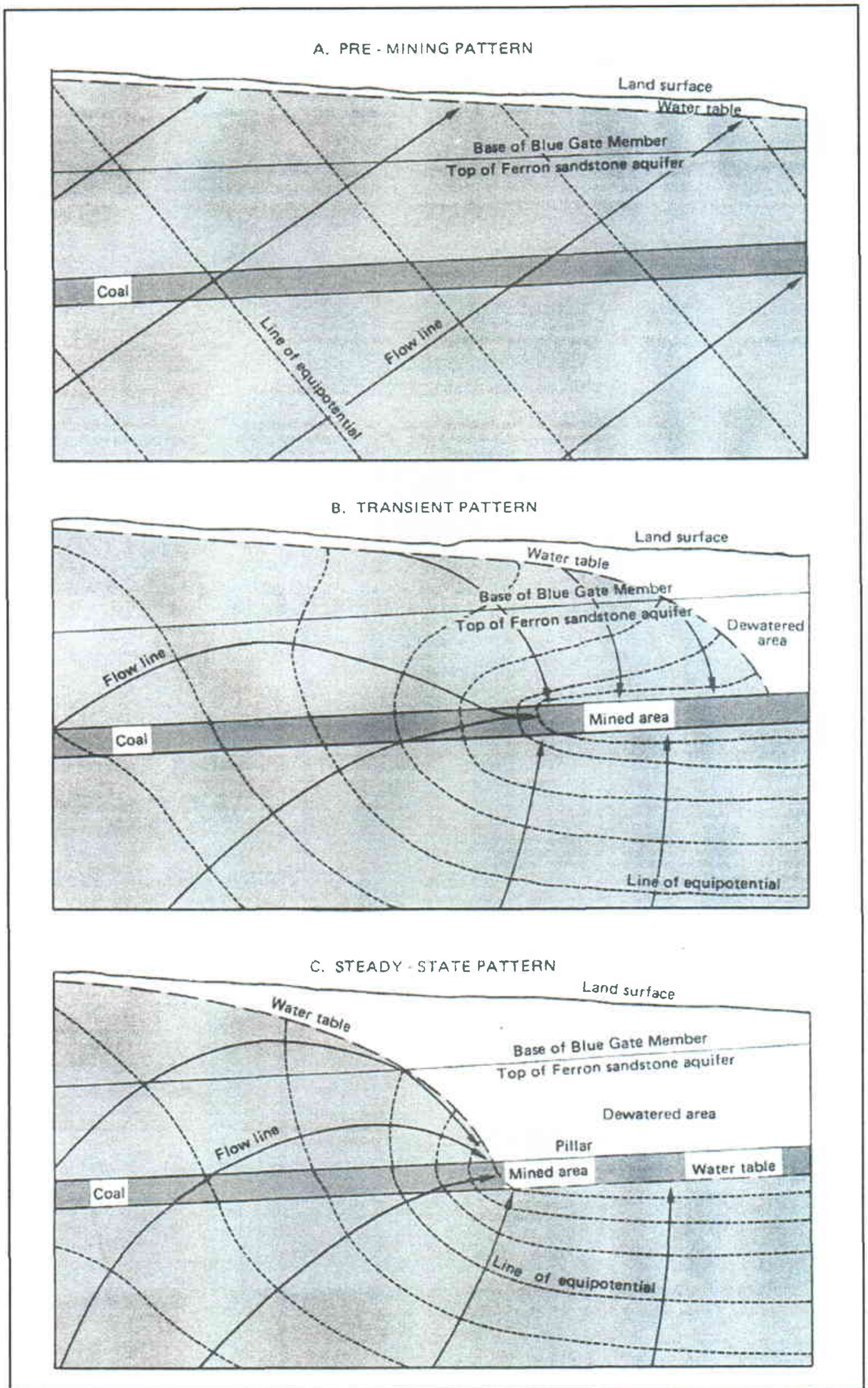


Figure VI-20B. Approximate Pre-mining, Transient, and Steady-state groundwater flow around the Emery Mine (from Lines, 1987)

The amount of water used underground was estimated from an examination of Figure VI-20A. As noted, substantially less water was discharged from the mine in 2002 through 2005, after the temporary shutdown, than during prior years. Data contained in Appendix VI-9 indicated that average mine-water discharge was as follows for the noted periods:

- Prior to temporary shutdown (1979-1990) = 0.93 cfs
- During temporary shutdown (1991-2001) = 1.03 cfs
- After temporary shutdown (2002-2005) = 0.63 cfs

Prior to shutdown, one continuous miner was in operation, resulting in some underground usage of water. During shutdown, water conditions in the mine were maintained in a static condition, with no underground water usage. Following the restart of mining, a second continuous miner was added and coal production was increased, with increased underground water usage indicated by the decrease in water pumped from the mine. With average discharges of 1.03 cfs during the period of inactivity and 0.63 cfs following the restart of mining, it is estimated that in-mine water usage currently averages 0.40 cfs. Based on an average annual mined area of 18.1 acres during the period of 2002 to 2005 (see Plate VI-6A), in-mine water usage is estimated to be 0.022 cfs/acre under current operational conditions.

Vertical inflow to the mine was estimated using two analytical methods. Each method is limited in its application to simplified flow situations, assuming that the aquifer is of infinite areal extent with uniform thickness.

The first method used to estimate vertical mine-water inflow was the steady-state tunnel inflow equation, presented by Freeze and Cherry (1979)[3]. This method assumes that the mine acts as an infinitely long tunnel in a homogeneous, isotropic porous medium. Under this assumption, the rate of ground water inflow Q_o per unit length of tunnel can be calculated using the following equation:

$$Q_o = \frac{2\pi K H_o}{2.3\log(2H_o / r)}$$

where r is the tunnel radius, Ho is the depth from the potentiometric surface to the center of the tunnel, and K is the hydraulic conductivity, with all units being compatible.

The second method used to estimate vertical mine-water inflow was the Hantush equation presented by Singh and Atkins (1985)[4]. This equation, which best fit the Emery conditions and assumes that the aquifer is homogeneous, isotropic, and pumped at a constant rate, is applied to large underground openings as illustrated in Figure VI-20C. Inflow to the mine is calculated by:

$$Q = 2\pi TDG(\lambda, r/B)$$

$$\lambda = Tt / r^2 S$$

$$r/B = r(K' / KLL')^{\frac{1}{2}}$$

[3] Freeze, R.A. and J.A. Cherry. 1979. Groundwater. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
[4] Singh, R.N. and A.S. Atkins. 1985. Analytical Techniques for the Estimation of Mine Water Inflow. International Journal of Mining Engineering. Vol. 3, pp. 65-77.

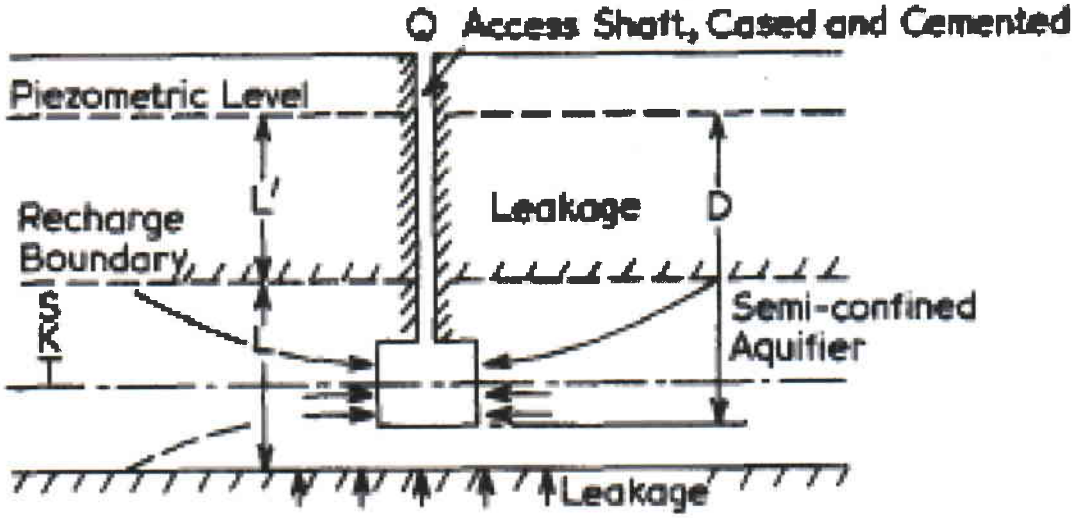


FIGURE VI-20C. Conceptual Hantush Flow Model (from Singh and Atkins, 1985).

where B is the leakage factor; D is drawdown to a level H from the original head H_0; $G(\lambda, r/B)$ is the Hantush well function; K is the aquifer hydraulic conductivity; K' is the aquitard hydraulic conductivity; L is the thickness of the formation being dewatered; L' is the aquitard thickness, Q is the quantity of inflow; r is the radius at which drawdown occurs; and t is elapsed time, with all units being compatible.

Mine-water discharge rates were estimated using the two methods described above for the period of 1980 through 1990. These calculations were then compared with measured discharge rates during the same period as a means of determining the best approach for estimating future conditions.

Preliminary calculations using the two methods indicated that the Hantush equation was a much better predictor of mine-water inflow than was the tunnel inflow equation. To more accurately predict inflow, the average hydraulic conductivity of the aquifer was therefore derived by calibration using the Hantush equation, attempting to mimic measured discharge rates as closely as possible. Based on this exercise, the average hydraulic conductivity of the Ferron Sandstone overlying the IJ seam was determined to be 0.20 ft/day. This value compares well with aquifer data presented previously in this chapter and independent data presented by Lines et al. (1983).[5] Assuming an aquifer thickness of 400 feet, the transmissivity data presented in Table VI-4 of this MRP convert to hydraulic conductivities ranging from 0.01 to 1.9 ft/day and averaging 0.9 ft/day. Laboratory hydraulic conductivity data provided by Lines et al. (1983) ranged from 2.6×10^{-6} to 0.77 ft/day, averaging 0.11 ft/day in the horizontal direction and 0.076 ft/day in the vertical direction. Hydraulic conductivities derived from field tests summarized by Lines et al. (1983) ranged from 0.025 to 2.0 ft/day, averaging 0.55 ft/day (again assuming an aquifer thickness of 400 feet).

[5] Lines, G.C., D.J. Morrisey, T.A. Ryder, and R.H. Fuller. 1983. Hydrology of the Ferron Sandstone Aquifer and Effects of Proposed Surface-Coal Mining in Castle Valley, Utah. U.S. Geological Survey Water-Supply Paper 2195. Alexandria, Virginia.

Results of the mine-water discharge calculations for the period of 1980 through 1990, using the Hantush and tunnel inflow equations, are summarized in Table VI-23A and detailed in Appendix VI-9. Each set of calculations accounted for lateral groundwater inflow and in-mine water usage, as outlined above. The equations were able to account for less inflow as the mine expanded since vertical inflow was assumed to enter the mine only in the area of current mining. As indicated in Table VI-23A and Figure VI-20D, the Hantush equation provides a reasonable estimate of mine water discharge. Hence, this equation was used to predict future mine-water discharge rates.

Table VI-23A. Estimated mine-water discharge rates using two analytical methods

Year	Mine-Water Discharge Rate (cfs)		
	Measured	Hantush equation	Tunnel inflow equation
1980	1.11	1.05	11.38
1981	0.68	0.96	1.38
1982	1.07	1.04	7.42
1983	1.20	1.08	1.98
1984	1.00	0.98	2.13
1985	0.80	0.66	7.60
1986	0.60	0.79	1.67
1987	1.00	1.09	2.95
1988	1.10	1.03	7.13
1989	0.90	0.95	12.10
1990	0.99	1.07	2.47
Average	0.95	0.97	5.29

Predicted mine-water discharge rates through the period of the current mine plan (2013) are summarized in Table VI-23B, based on the Hantush equation and accounting for mine-water inflow and usage as described above. Spreadsheets detailing these calculations are provided in Appendix VI-9. Based on these calculations, discharge rates are expected to average 1.50 cfs, ranging from about 1.2 to 2.0 cfs during the calculation period. Variations in discharge rates are anticipated depending on the depth of mining below the potentiometric surface and the area over which mining will occur. These estimates are based on the assumed hydraulic conductivity of 0.20 ft/day (i.e., the calibrated value arrived at in the comparison with measured historic discharge rates). Since pillars had been pulled prior to the 1991 temporary shutdown, this hydraulic conductivity is assumed to be representative of post-subsidence conditions. Hence, the estimates presented in Table VI-23B assume full extraction of the coal.

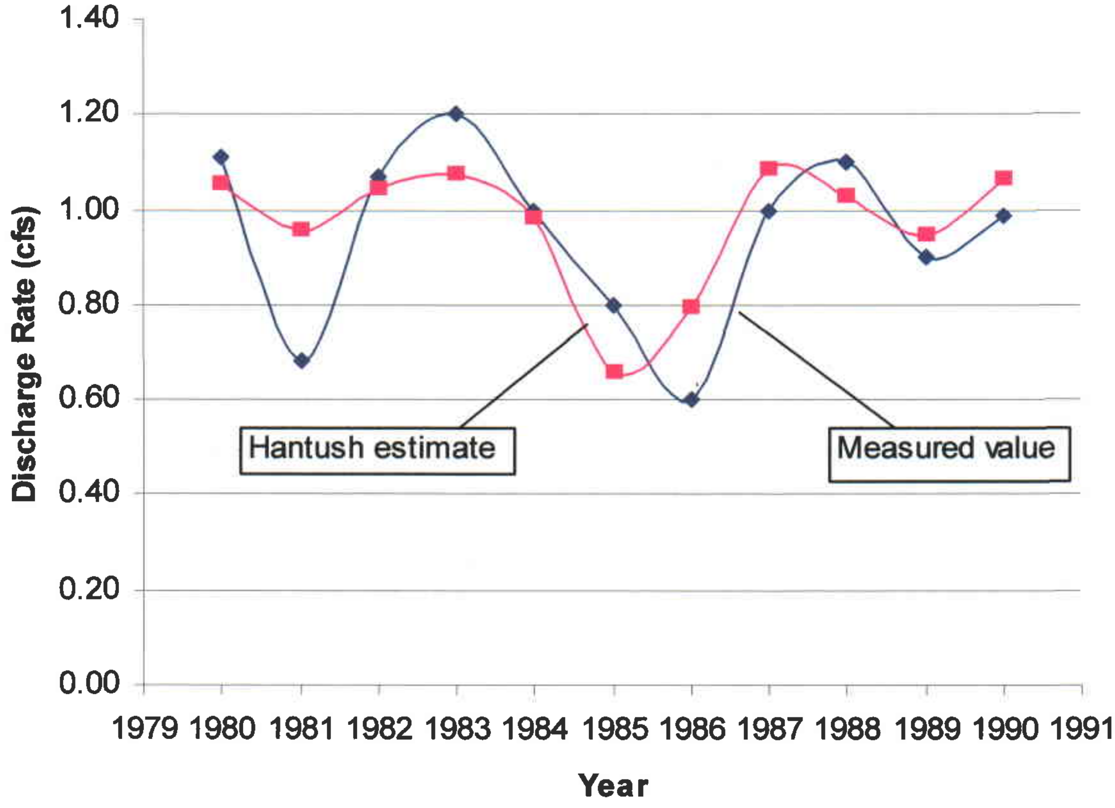


Figure VI-20D. Comparison of measured and calculated mine discharge data (Hantush equation)

Table VI-23B. Predicted mine water discharge rates

Year	Predicted Discharge (cfs)
2006	1.29
2007	1.19
2008	1.33
2009	1.77
2010	1.28
2011	1.52
2012	1.63
2013	1.98
Average	1.50

~~A mine water inflow model developed by Consolidation Coal Company's research group was used to simulate the groundwater hydrology in the vicinity of the Emery Mine. The model, known~~

~~as CONOSIM, projects that additional drawdowns of 8-48 feet will occur in the upper Ferron monitoring wells during the 1990-1995 mining period and that 45-80 feet of drawdown will occur in the middle Ferron monitoring wells. Drawdown data for individual monitoring wells appear in Table VI-24. As the mine continues to expand, a greater volume of water will be withdrawn from the Ferron aquifer and pumped to the surface. Inflows to the mine are expected to increase from the 1.0 cfs rate experienced in 1989 to a projected value of 1.5 cfs in 1995. The simulated inflow results generated by CONOSIM are summarized below:~~

~~Mine Plan Year~~	~~Peak Inflow (cfs)~~
~~1990~~	~~1.05~~
~~1991~~	~~1.1~~
~~1992~~	~~1.2~~
~~1993~~	~~1.3~~
~~1994~~	~~1.4~~
~~1995~~	~~1.5~~

~~A discussion of the CONOSIM model is found later in this section.~~

~~Potentiometric surface maps based on these drawdowns were developed for the upper Ferron aquifer. These contours are shown on Plates VI-7. Due to the limited amount of data available for the midd1e Ferron, caused by the uncertain condition of wells R2(m) and H(m), a potentiometric surface map for the middle Ferron was not made. Since the lower Ferron aquifer remains relatively unaffected by mining as shown by static water level hydrographs in Figure VI-9 no potentiometric surface maps were generated nor were drawdown potentials evaluated.~~

~~Although incremental drawdowns predicted to occur in the upper Ferron are small, their impact on water users in the area must be viewed from a cumulative aspect. In trying to assess the cumulative drawdown, Plate VI-8 was generated in which the expected potentiometric surface in 1995 is compared with a 1979 potentiometric surface map prepared by Lines and Morrissey in their USGS study of the Ferron sandstone aquifer. Lines and Morrissey's 1979 map is recreated as Plate VI-9. This comparison subtracts the 1995 surface from the 1979 surface and creates a contour map that displays the cumulative drawdown which is expected to occur in the upper Ferron by 1995. In reality this drawdown is constrained by the elevation of the bottom of the upper Ferron sandstone unit. In areas where the elevation of the cumulative predicted drawdown would be lower than the bottom of the upper Ferron sandstone, the Kmf(u) aquifer will be drained. The area where this is expected to occur is shown on Plate VI-8.~~

~~From the list of ground water users in Table VI-20 the only wells that need to be evaluated for mining impacts are the Lewis, Bryant and Town of Emery wells. The Lewis and Bryant wells are situated within the permit area. The proposed mine plan shows that mining will get no closer than three miles of the Town of Emery's wells.~~

~~Drillers' logs and well completion summaries provided in Appendix VI-2 describe well depths, elevations and completion zones for these wells. These data are listed below along with projected draw down elevations from Table VI-24.~~

~~Well ID~~	~~Aquifer~~	~~Completion Depth Feet~~	~~Completion Depth Elevation~~	~~Projected 1995 Drawdown Elev.~~
~~Bryant~~	~~Kmf(u)~~	~~402~~	~~5,619~~	~~5,720~~

~~Lewis~~	~~Kmf(u)~~	~~608~~	~~5,410~~	~~5,752~~
~~Town of Emery~~				
~~Well #1~~	~~Kmf(l)~~	~~1614~~	~~4,711~~	~~--~~
~~Well #2~~	~~Kmf(u&m)~~	~~1450~~	~~4,875~~	~~--~~

~~Plate V1-7 shows that the upper Ferron aquifer water supply for the Bryant and Lewis wells will not be drained during the proposed mining term and that these wells should remain serviceable. Since the Town of Emery Well #1 is developed in the lower Ferron aquifer, no adverse impacts to the well are anticipated and any drawdowns should be minimal. The Town's well #2 which is developed in both the upper and middle Ferron aquifers remains outside the area of mining influence for the upper Ferron as shown by potentiometric contours on Plate VI-7. An evaluation of effects on the middle Ferron component is best made by examining static water levels for the following wells: I(m), EMRIA1 and FC346WW. Well I(m) lies within 1,000 feet of the mine and has shown a 95.1 ft. decline from April 1983- June 1990 or 13.6 feet per year. The EMRIA1 and FC346WW wells which are located 2 and 1.2 miles respectively from the underground mine workings are also developed in both the upper and middle Ferron aquifers and should give some indication of what effect mining could have on the Town's Well #2. Over the same seven year period evaluated for Well I(m), the EMRIA1 and FC346WW wells have shown annual water level declines of 0.6 feet and 6.6 feet respectively. Based on this reasoning, it is consistent to state that wells located beyond the 2 mile zone of influence as identified by the EMRIA1 well would experience water level declines of less than 0.6 feet per year.~~

~~CONOSIM Model Discussion~~

~~Projections of the inflow rates and drawdown profiling were performed via the CONOSIM (See Owili-Eger 1982) computer model. The map in Figure VI-21 shows the modeled area bounded by heavy lines. This area is approximately 5 by 3 miles in extent and encompasses the present and future mining areas. Figure VI-22, which shows a geologic section of the Emery Mine area, labels the geologic region that was modeled. This region includes the upper and middle Ferron sandstone units which are above and below the coal seam being mined.~~

~~The hydraulic parameters of the upper Ferron sandstone were determined by a pump test conducted by Consol in the area during September 1985 (See Section UMC 783.15). The test results established that the upper Ferron has a horizontal hydraulic conductivity of 0.8 foot per day and a storage coefficient of 0.0004. The approximate value of the vertical permeability of the same zone is 0.005 foot per day, and the sandstone porosity was assumed to be 10 percent. These values were also used for the middle Ferron aquifer.~~

~~In the simulation of the mine inflow quantities, the following modeling assumptions were used:~~

~~1. Most of the water entering the mine voids is from the upper Ferron sandstone aquifer. Minor quantities may come from leakage from the Blue Gate Shale member, but these are considered insignificant. Seepages from the lower aquifers are negligible, since some coal is left in the floor and there are thin layers of shale in the immediate floor strata.~~

~~2. The room-and-pillar mining method does not cause massive caving of the roof until after the retreat mining of the coal pillars. The extent of the mine void is considered dynamic from one simulation time period to the next (if desired). However, during any single time step, the void is assumed static. If massive caving occurs, the model can be instructed to evaluate and update nodal or block characteristics based on the concept developed by Snow (1968).~~

~~TABLE VI-24~~

~~PREDICTED DRAWDOWNS IN THE UPPER FERRON SANDSTONE WELLS~~
~~1990-1995~~

~~Well ID~~	~~Water Level Elevation at the end of:~~ ~~1989 (ft)~~	~~1995 (ft)~~	~~Drawdown (ft)~~
~~AA~~	~~5858~~	~~5850~~	~~8~~
~~Bryant~~	~~5734~~	~~5720~~	~~14~~
~~Emira 3~~	~~6021~~	~~6010~~	~~11~~
~~Lewis~~	~~5762~~	~~5750~~	~~12~~
~~H~~	~~6174~~	~~6160~~	~~14~~
~~Muddy #1~~	~~5940~~	~~5930~~	~~10~~
~~Muddy #2~~	~~5949~~	~~5930~~	~~19~~
~~TP~~	~~5638~~	~~5620~~	~~18~~
~~USGS 1-2~~	~~5946~~	~~5900~~	~~46~~

~~PREDICTED DRAWDOWNS IN THE MIDDLE FERRON SANDSTONE WELLS~~
~~1990-1995~~

~~Well ID~~	~~Water Level Elevation at the end of:~~ ~~1989 (ft)~~	~~1995 (ft)~~	~~Drawdown (ft)~~
~~H*~~	~~5900 (?)~~	~~5825 (?)~~	~~75 (?)~~
~~I~~	~~5880~~	~~5800~~	~~80~~
~~AA~~	~~5889~~	~~5844~~	~~45~~

~~* Well integrity from March 1988 to the present is questionable.~~

~~3. Recharge to the upper Ferron sandstone aquifer occurs along the Joe's Valley-Paradise Fault graben and possibly from precipitation at the outcrops as well as downward leakage from the Blue Gate Shale Member of the Mancos Shale.~~

~~4. The upper Ferron aquifer is treated as a confined ground water system, with the Blue Gate Shale and the thin shale layer in the floor of the IJ coal seam acting as the confining strata. Since CONOSIM is a double-porosity model, both fractured and unfractured flow characteristics are considered.~~

~~Calibration of CONOSIM was accomplished by comparing the computed mine discharge during a steady-state simulation with the actual measured mine inflow. The model-generated inflow averaged about 1.15 cfs, and the current mine inflow is about 1.0 cfs.~~

~~The simulation results generated via CONOSIM are summarized below:~~

~~Mine Plan Year~~	~~Peak Inflow (cfs)~~
~~1990~~	~~1.05~~
~~1991~~	~~1.1~~
~~1992~~	~~1.2~~
~~1993~~	~~1.3~~
~~1994~~	~~1.4~~
~~1995~~	~~1.5~~

~~CONOSIM has a built-in index array which is interrogated either every iteration or time step to check the status or condition of each node or element. Depending upon the user-specified commands or requirements, appropriate signals are generated. These signals are conveyed to appropriate subprograms, where specific actions are executed. CONOSIM model has been documented in Owili-Eger (1980).~~

~~The caving height used in this study was about ten times the mining height. When an element or block fractures and caves, the model generates new characteristics based on the approach developed by Snow (1968). The interactions of the fractured material zones are handled numerically by the computer through the combination of altered hydraulic and elastic properties and the resulting pressures.~~

~~CONOSIM can handle up to 400 inflow nodes with either constant or time-varying rates. Thus the "high long-term groundwater inflow areas" do not present any modeling difficulties.~~

~~Although CONOSIM is a powerful three-dimensional model, the complex nature of a dynamic mining environment, coupled with geologic uncertainties, cannot be overlooked. The hydrologic parameters generated are, at best, approximations. However, they have been obtained via the best available technology and are far superior to analytical or empirical techniques. As additional data are obtained from actual inflows and water level monitoring (seasonal), our predictions can then be refined and upgraded.~~

<u>Ground Water Quality Impacts</u>

Potential Upper Ferron Contamination:

Mining of the IJ coal seam is not expected to produce any wide-spread changes in the existing water quality within the water-bearing materials. Although the potential exists for downward movement of Blue Gate Shale water into the upper Ferron sandstone due to water level declines caused by mining, the occurrence of such contamination is not generally indicated by water level comparisons for the Bluegate and upper Ferron or by water quality samples collected from the upper Ferron. Data from the group of wells which is centrally located above the mine workings perhaps demonstrates this relationship best. The wells at this site are TP(u), T1(bg) and T2(bg). The two Blue Gate wells are designed to show not only hydraulic communication with the underlaying upper Ferron sandstone but any communication, within the Blue Gate shale itself. This was accomplished by completing well T1(bg) from a 5-31 foot depth and Well T2(bg) from a 31-342 foot depth. The two Blue Gate wells have shown no decline in static water level values over the life of the wells and also do not show any independent fluctuations. At the same time, We1l TP(u) has shown a decline of 277.8 feet. These data suggest that water within the upper and lower levels of the Blue Gate shale is hydraulically connected and also suggests that at least in this location there is no communication with the upper Ferron sandstone. The other Blue Gate wells (AA, H, I, R2, USGS3-1 and

APPENDIX VI-9

Mine-Water Discharge Calculations

Added 12/08/06

Calibration Calculations and
Comparison with Historic Data

Added 12/08/06

Table 1. Upper Ferron Aquifer Groundwater Elevation Data (units: feet)

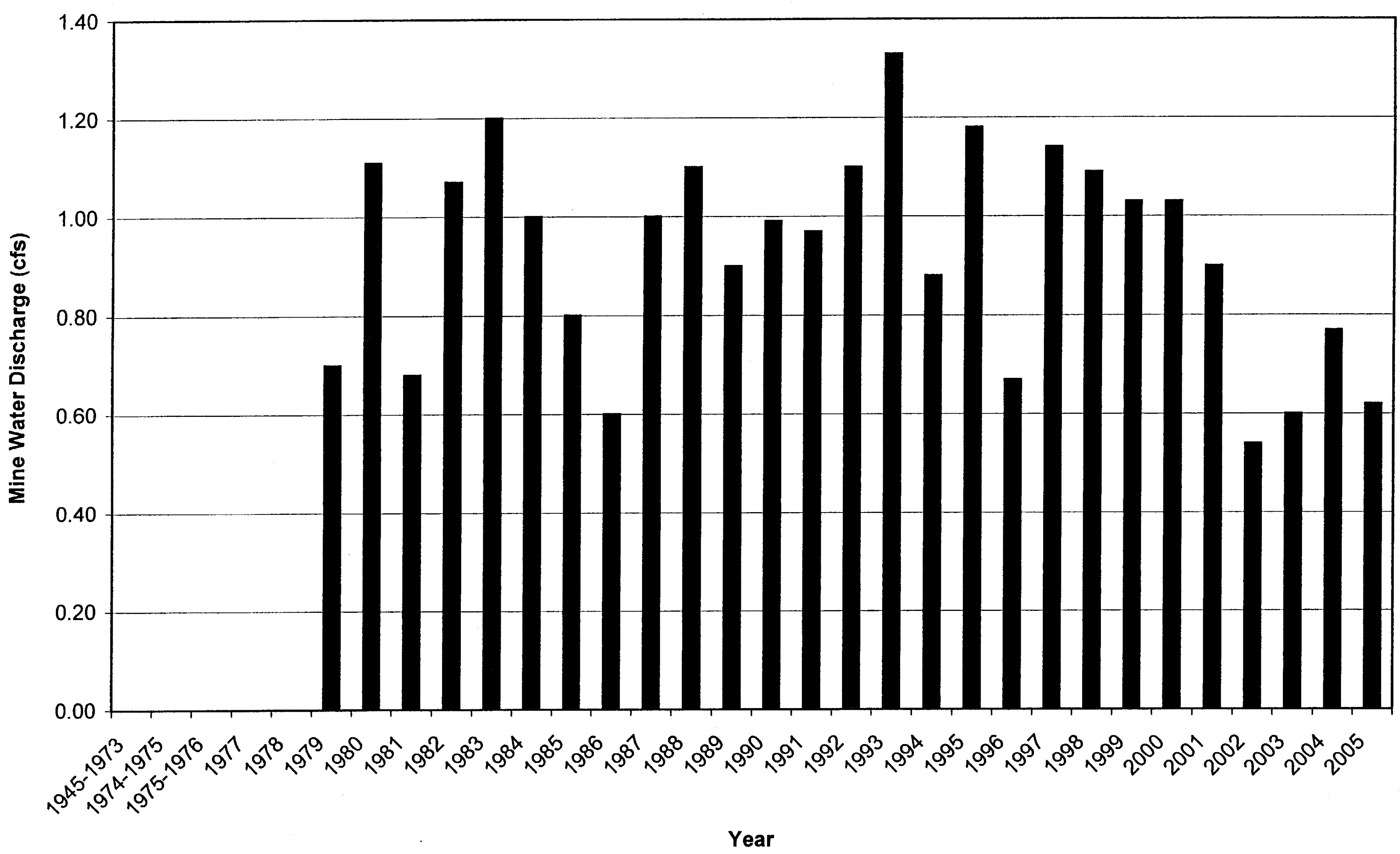
	Year							
Well	1979	1982	1983	1986	1989	1990	1995	Change
R2(U)	6030.4	6043.3	6036.3	5821.9	NA	5550.0	NA	480.4
TP	NA	5722.0	5709.0	5645.5	5637.7	5636.0	5620.0	102.0
AA(U)	5980	5869.5	5863.3	5860.8	5858.2	5858.0	5850.0	130.0
BRYANT	6030.4	5807.2	5798.0	5706.3	5733.9	5732.0	5720.0	310.4
EMRIA3	6041.1	6022.8	6020.0	6028.9	6020.5	6030.0	6010.0	31.1
FC346WW	6095.5	6072.8	6069.1	6058.2	6028.1	6022.0		
H(U)	6187.8	6160.0	6160.0	6173.4	6173.6	6176.0	6160.0	27.8
..	5898.9	5940.4	5939.8	5939.8	5940.0	5940.0	5930.0	-31.1
MUDDY2(U)	6000.8	5975.4	5973.7	5955.6	5948.1	5848.0	5930.0	70.8
USGS1-2(U)	6022.3	5991.6	5958.5	5958.6	5945.9	5944.0	5900.0	122.3
I2	N/A	NA	NA	5711.0	5705.2			
EMEIA2	6053.5	6056.6	6053.5	6063.2	6041.9			
FC343	6061.5							
LEWIS(U)	6038.5	5840.1	5830.1	5751.2	5762.2	5759.0	5750.0	
MUDDY4	6051.8	6045.9	6043.8					
USGS1-3	6047.8							
USGS1-4	6306.8						6307.0	
USGS2-4	6003.0							

Table 2. Emery Mine discharge data.

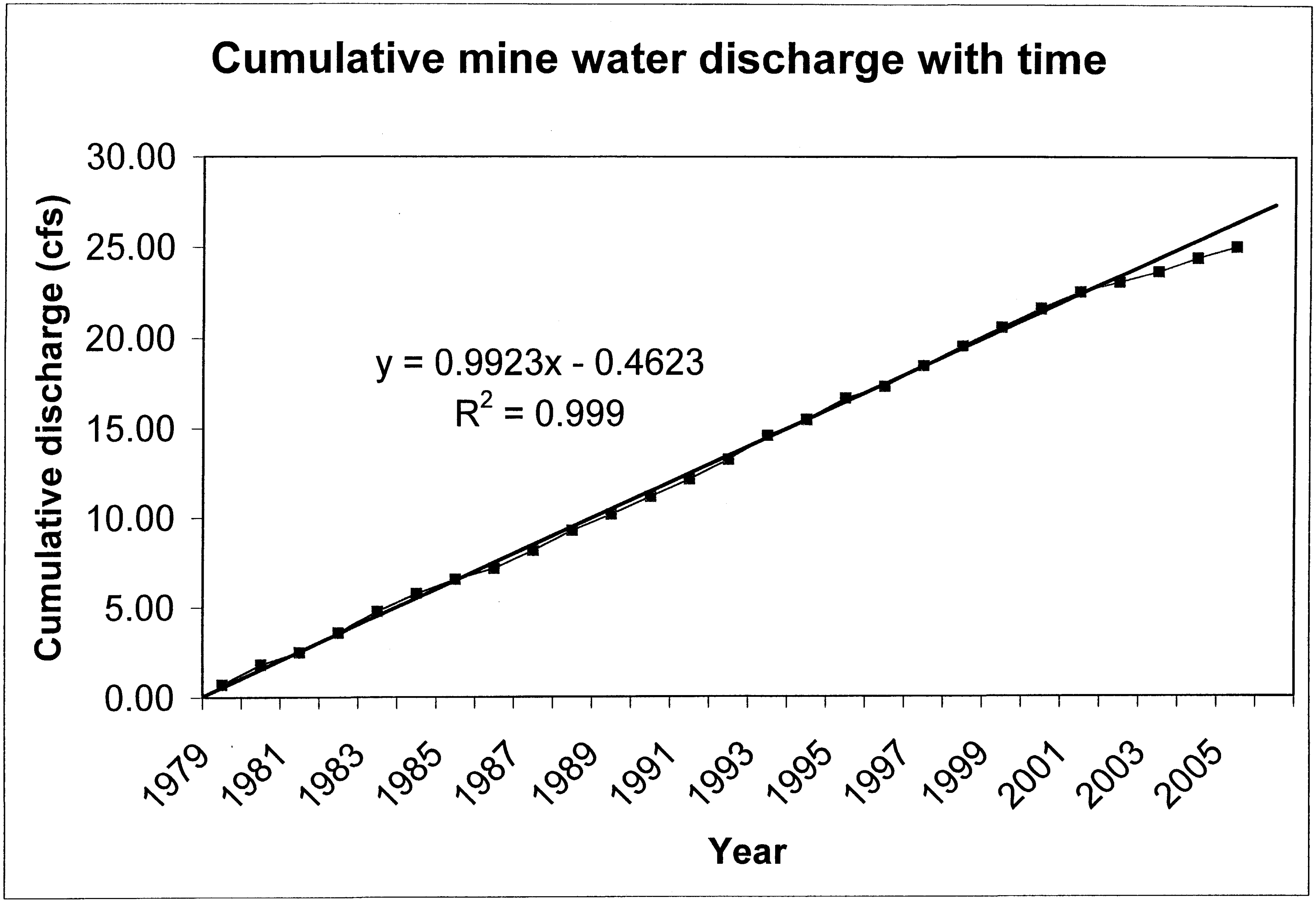
Time	Mined Area (acres)	Mine Discharge (cfs)	
		Average	Cumulative
1945-1973	117.15		
1974-1975	48.61		
1975-1976	46.77		
1977	19.63		
1978	43.09		
1979	6.75	0.70	0.70
1980	56.12	1.11	1.81
1981	6.90	0.68	2.49
1982	37.26	1.07	3.56
1983	18.94	1.20	4.76
1984	36.88	1.00	5.76
1985	76.05	0.80	6.56
1986	28.98	0.60	7.16
1987	28.06	1.00	8.16
1988	87.25	1.10	9.26
1989	56.73	0.90	10.16
1990	27.29	0.99	11.15
1991	0.00	0.97	12.12
1992	0.00	1.10	13.22
1993	0.00	1.33	14.55
1994	0.00	0.88	15.43
1995	0.00	1.18	16.61
1996	0.00	0.67	17.28
1997	0.00	1.14	18.42
1998	0.00	1.09	19.51
1999	0.00	1.03	20.54
2000	0.00	1.03	21.57
2001	0.00	0.90	22.47
2002	11.50	0.54	23.01
2003	10.27	0.60	23.61
2004	14.87	0.77	24.38
2005	28.06	0.62	25.00

Statistical Analysis		
Mean	0.87	18.68 cfs
Std. Deviation	0.21	4.52 cfs
Max	1.33	25.00 cfs
Min	0.54	11.15 cfs

Avg. inflow prior to temp. shutdown (1979-1990)= 0.93 cfs
Avg. inflow during temp. shutdown (1991-2001)= 1.03 cfs
Avg. inflow following restart of mining (2002-2005)= 0.63 cfs



Average Mine Water Discharge By Year


Cumulative mine water discharge with time
y = 0.9923x - 0.4623
R2 = 0.999
Cumulative discharge (cfs)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Year

Estimated mine-water discharge from the Emery Mine (1980-1990) based on the Hantush Equation
(see Singh and Atkins, 1985)

Assume: (1) The potentiometric surface is as indicated in Table 1

(2) Average dip of coal bed (ft/ft) = 0.067 (from Chap. V of MRP)

(3) Hydraulic conductivity: 0.20 feet/day (Calibrated value. Compare with site data in Chap. VI of MRP and Lines et al. [1983])
Assumed transmissivity 80 ft^2/day (see Chap. VI of MRP and Lines et al. [1983])
Storage coefficient 1.59E-03 (see Chap. VI of MRP)
K in Bluegate shale 4.40E-04 ft/day (see 2005 slug test data)

(4) The Ferron Sandstone averages 400 feet in thickness in the mine area (see Chap. V of MRP)

(5) The IJ coal seam has an average thickness of 20 feet
The average thickness of the Upper Ferron sandstone above the IJ coal seam is 80 feet

(6) Mine water usage: 0.0221 cfs/acre (using 2002,2004, 2005 data when pillars are pulled out; see data below)
Avg. discharge from mine during temporary shutdown (1991-2001): 1.03 cfs (see Table 2)
Avg. discharge from mine following re-start (2002-2005): 0.63 cfs
Δflow 0.40 cfs (represents water usage in the mine)

(7) Subsurface inflow: Lateral recharge comes from Joes valley fault zone,
The recharge length 2.17 mile after 1990
Average discharge from mine during period of temporary shutdown (1991-2001): 1.03 cfs
Recharge per unit length = 0.47 cfs/mile

Analytical Model: Hantush Equation: Q=2πTDG(λ,r/B)
λ=Tt/r^2S
r/B=r(K'/KLL')^1/2

Year	**1980 (1)**	(using 1979 Potentiometric surface)						
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)			
	787	420	330	400	365			
Calculation	λ	2.97E+01	r/B	0.047631	G value	0.4	Q	0.98 cfs
Year	**1980 (2)**	(using 1979 Potentiometric surface)						
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)			
	400	215	125	400	365			
Calculation	λ	1.15E+02	r/B	0.039335	G value	0.35	Q	0.44 cfs
Mine facility usage:								1.24 cfs
Lateral recharge								0.87 cfs
Total Mine Discharge:								1.05 cfs
Year	**1981**	(using average of 1979 and 1982 Potentiometric surface)						
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)			
	300	121	31	400	365			
Calculation	λ	2.04E+02	r/B	0.05924	G value	0.29	Q	0.20 cfs
Mine facility usage:								0.15 cfs
Lateral recharge								0.90 cfs
Total Mine Discharge:								0.96 cfs
Year	**1982(1)**	(using 1982 Potentiometric surface)						
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)			
	472	48	0	400	365			
Calculation	λ	8.24E+01	r/B	1	G value	0.545	Q	0.15 cfs
Year	**1982(2)**	(using 1982 Potentiometric surface)						
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)			
	541	248	158	400	365			
Calculation	λ	6.27E+01	r/B	0.04732	G value	0.34	Q	0.49 cfs
Year	**1982(3)**	(using 1982 Potentiometric surface)						
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)			
	670	100	10	400	365			
Calculation	λ	4.09E+01	r/B	0.232943	G value	0.545	Q	0.32 cfs
Mine facility usage:								0.82 cfs
Lateral recharge								0.90 cfs
Total Mine Discharge:								1.04 cfs

Year	**1983**	(refer to 1979 Potentiometric surface at well FC343)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	724	260	170	400	365		
Calculation	λ	3.50E+01 r/B		0.061051 G value		0.39 Q	0.59 cfs
Mine facility usage:							0.42 cfs
Lateral recharge							0.90 cfs
Total Mine Discharge:							1.08 cfs

Year	**1984(1)**	(refer to 1983 Potentiometric surface at well USGS1-2)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	724	150	60	400	365		
Calculation	λ	3.50E+01 r/B		0.102763 G value		0.41 Q	0.36 cfs
Year	**1984(2)**	(refer to 1983 Potentiometric surface at well USGS1-2)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	500	160	0	400	365		
Calculation	λ	7.35E+01 r/B		1 G value		0.545 Q	0.51 cfs
Mine facility usage:							0.81 cfs
Lateral recharge							0.93 cfs
Total Mine Discharge:							0.98 cfs

Year	**1985(1)**	(using 1983 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	540	263	173	400	365		
Calculation	λ	6.30E+01 r/B		0.045138 G value		0.35 Q	0.54 cfs
Year	**1985(2)**	(using 1986 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	761	289	199	400	365		
Calculation	λ	3.17E+01 r/B		0.059311 G value		0.42 Q	0.71 cfs
Year	**1985(3)**	(using 1986 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	100	50	0	400	365		
Calculation	λ	1.84E+03 r/B		1 G value		0.3 Q	0.09 cfs
Mine facility usage:							1.68 cfs
Lateral recharge							1.01 cfs
Total Mine Discharge:							0.66 cfs

Year	**1986(1)**	(using 1986 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	449	100	10	400	365		
Calculation	λ	9.11E+01 r/B		0.156107 G value		0.33 Q	0.19 cfs
Year	**1986(2)**	(using 1986 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	446	66	0	400	365		
Calculation	λ	9.23E+01 r/B		1 G value		0.545 Q	0.21 cfs
Mine facility usage:							0.64 cfs
Lateral recharge							1.03 cfs
Total Mine Discharge:							0.79 cfs

Year	**1987(1)**	(using 1986 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	366	53	0	400	365		
Calculation	λ	1.37E+02 r/B		1 G value		0.406 Q	0.13 cfs
Year	**1987(2)**	(using 1986 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	500	286	196	400	365		
Calculation	λ	7.35E+01 r/B		0.039266 G value		0.33 Q	0.55 cfs
Mine facility usage:							0.62 cfs
Lateral recharge							1.03 cfs
Total Mine Discharge:							1.09 cfs

Year	**1988(1)**	(using 1989 Potentiometric surface)						
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
		400	286	196	400	365		
Calculation		λ	1.15E+02 r/B		0.031413 G value		0.309 Q	0.51 cfs
Year	**1988(2)**	(using 1989 Potentiometric surface)						
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
		400	286	196	400	365		
Calculation		λ	1.15E+02 r/B		0.031413 G value		0.309 Q	0.51 cfs
Year	**1988(3)**	(using 1989 Potentiometric surface)						
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
		570	480	390	400	365		
Calculation		λ	5.65E+01 r/B		0.031734 G value		0.32 Q	0.89 cfs
Year	**1988(4)**	(using 1989 Potentiometric surface)						
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
		625	0	0	400	365		
Calculation		λ	4.70E+01 r/B		1 G value		0.2 Q	0.00 cfs
Mine facility usage:								1.92 cfs
Lateral recharge								1.03 cfs
Total Mine Discharge:								1.03 cfs

Year	**1989(1)**	(using 1989 Potentiometric surface)						
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
		683	360	270	400	365		
Calculation		λ	3.94E+01 r/B		0.0457 G value		0.36 Q	0.75 cfs
Year	**1989(2)**	(using 1989 Potentiometric surface)						
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
		256	250	160	400	365		
Calculation		λ	2.80E+02 r/B		0.022251 G value		0.284 Q	0.41 cfs
Year	**1989(3)**	(using 1989 Potentiometric surface)						
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
		502	0	-90	400	365		
Calculation		λ	7.29E+01 r/B		1 G value		0.2 Q	0.00 cfs
Mine facility usage:								1.25 cfs
Lateral recharge								1.03 cfs
Total Mine Discharge:								0.95 cfs

Year	**1990(1)**	(using 1990 Potentiometric surface)						
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
		272	175	85	400	365		
Calculation		λ	2.48E+02 r/B		0.032437 G value		0.29 Q	0.30 cfs
Year	**1990(2)**	(using 1990 Potentiometric surface)						
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
		272	175	85	400	365		
Calculation		λ	2.48E+02 r/B		0.032437 G value		0.29 Q	0.30 cfs
Year	**1990(3)**	(using 1990 Potentiometric surface)						
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
		478	15	.0	400	365		
Calculation		λ	8.04E+01 r/B		1 G value		0.545 Q	0.05 cfs
Mine facility usage:								0.60 cfs
Lateral recharge								1.03 cfs
Total Mine Discharge:								1.07 cfs

Estimated mine-water discharge from the Emery Mine (1980-1990) based on the tunnel inflow equation
(see Freeze and Cherry, 1979)

Assumed avg. hydraulic conductivity: 0.20 ft/day

Vertical mine-water inflow (see Plate VI-6A for mine extents and dimensions each year):

Year	Ho	L	Qo	Vert. Inflow (cfs)
1980(1)	420	6875	0.001517508	10.43
1980(2)	215	1406	0.000931616	1.31
1980				11.74
1981	121	990	0.000632506	0.63
1982(1)	48	1625	0.000375576	0.61
1982(2)	248	5000	0.001030807	5.15
1982(3)	100	2800	0.000561132	1.57
1982				7.34
1983	260	1400	0.001066302	1.49
1984(1)	150	1400	0.000727952	1.02
1984(2)	160	1312.5	0.000760132	1.00
1984				2.02
1985(1)	263	2025	0.001075131	2.18
1985(2)	289	4800	0.001150955	5.52
1985(3)	50	1500	0.000382827	0.57
1985				8.28
1986(1)	100	1000	0.000561132	0.56
1986(2)	66	1625	0.000440957	0.72
1986				1.28
1987(1)	53	1000	0.000393733	0.39
1987(2)	286	1875	0.001142268	2.14
1987				2.54
1988(1)	286	875	0.001142268	1.00
1988(2)	286	1375	0.001142268	1.57
1988(3)	0	2000	0	0.00
1988(4)	480	3250	0.001678673	5.46
1988				8.03
1989(1)	360	5125	0.001352454	6.93
1989(2)	250	5200	0.001036743	5.39
1989(3)	0	2750	0	0.00
1989				12.32
1990(1)	175	750	0.000807776	0.61
1990(2)	175	1250	0.000807776	1.01
1990(3)	15	1375	0.000313014	0.43
1990				2.05

Emery Mine Water Budget Prediction with the Tunnel Inflow Equation (all flows in cfs)

Year	Vertical Inflow	Horizontal Inflow	Total Mine Inflow	Facility Usage	Pump Discharge
1980	11.74	0.87	12.62	1.24	11.38
1981	0.63	0.90	1.53	0.15	1.38
1982	7.34	0.90	8.24	0.82	7.42
1983	1.49	0.90	2.40	0.42	1.98
1984	2.02	0.93	2.95	0.81	2.13
1985	8.28	1.01	9.28	1.68	7.60
1986	1.28	1.03	2.31	0.64	1.67
1987	2.54	1.03	3.57	0.62	2.95
1988	8.03	1.03	9.06	1.92	7.13
1989	12.32	1.03	13.35	1.25	12.10
1990	2.05	1.03	3.08	0.60	2.47
Average	5.25	0.97	6.22	0.92	5.29

Comparison of discharge estimates with measured values - Emery Mine, 1980-1990

Time	Mine Water Discharge (cfs)		
	Measured	Hantush	Tunnel
1980	1.11	1.05	11.38
1981	0.68	0.96	1.38
1982	1.07	1.04	7.42
1983	1.20	1.08	1.98
1984	1.00	0.98	2.13
1985	0.80	0.66	7.60
1986	0.60	0.79	1.67
1987	1.00	1.09	2.95
1988	1.10	1.03	7.13
1989	0.90	0.95	12.10
1990	0.99	1.07	2.47
Average	0.95	0.97	5.29

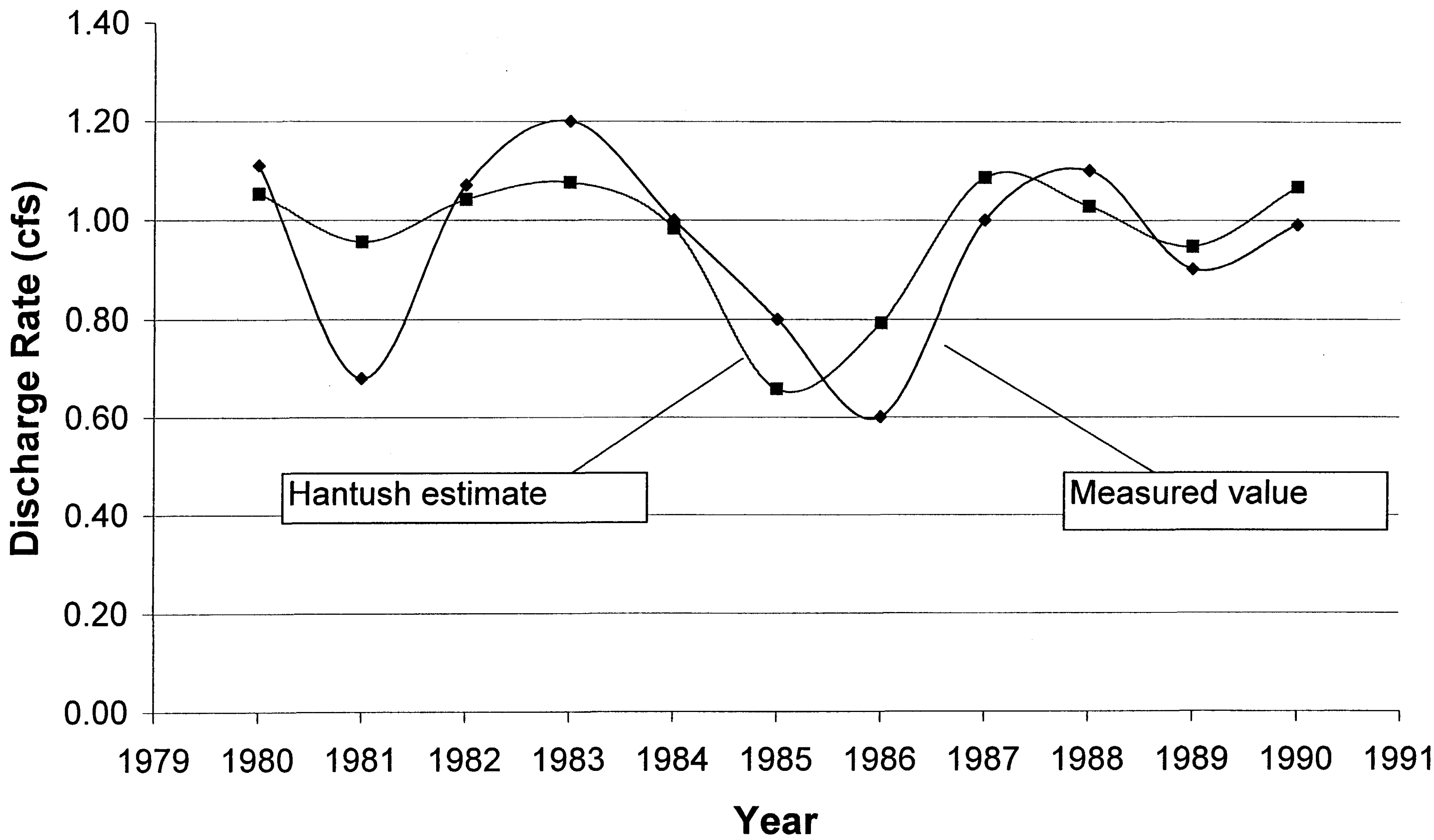


Figure VI-20C. Comparison of measured and calculated mine discharge data (Hantush equation)

Predictions of Future
Mine-Water Discharge

Added 12/08/06

Predicted future mine-water discharge from the Emery Mine (through 2013) based on the Hantush equation
(see Singh and Atkins, 1985)

Assume: **(1)** The potentiometric surface is as indicated for 1995 in Table 1

(2) Average dip of the coal bed (ft/ft) = 0.067

(3)

Hydraulic conductivity	0.20	feet/day	(Calibrated value)
Assumed transmissivity	80	ft^2/day	(see Chap. VI of MRP and Lines et al. [1983]))
a storage coefficient	1.59E-03		(see Chap. VI of MRP)
K in Bluegate shale	4.40E-04	ft/day	(see 2005 slug test data)

(4) The Ferron Sandstone averages 400 feet in thickness in the mine area

(5) The IJ coal seam has an average thickness of: 20 ft
The average thickness of the Upper Ferron sandstone above the IJ coal seam is: 80 ft

(6) Mine facility usage: 0.0221 cfs/acre
Based on: Average mine discharge from 1991-2001= 1.03 cfs
Average mine discharge from 2002-2005= 0.63 cfs
Difference (i.e., in-mine water usage)= 0.40 cfs
Historic mine areas (from Plate VI-6A)

(7) Horizontal inflow: Originates from the Joes Valley-Paradise fault zone
Mine length exposed to inflow from the fault zone: 2.17 mile
Assumes all inflow from 1991-2001 resulted from horizontal flow to the mine
Horizontal inflow per unit length of mine = 0.47 cfs/mile

(8) Future mine workings to be oriented as indicated on Plate VI-6A

Analytical Model: Hantush Equation: Q=2πTDG(λ,r/B)
λ=Tt/r^2S
r/B=r(K'/KLL')^1/2

Year	**2006(1)**	(using 1995 Potentiometric surface)							
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)			
		550	200	110	400	365			
Calculation		λ	6.07E+01	r/B	0.057656	G value	0.36	Q	0.42 cfs
Year	**2006(2)**	(using 1995 Potentiometric surface)							
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)			
		312	350	260	400	365			
Calculation		λ	1.89E+02	r/B	0.021274	G value	0.284	Q	0.58 cfs
Year	**2006(3)**	(using 1995 Potentiometric surface)							
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)			
		579	190	100	400	365			
Calculation		λ	5.48E+01	r/B	0.063658	G value	0.374	Q	0.41 cfs
Mine facility usage:									1.31 cfs
Lateral recharge									1.19
Total Mine Discharge:									1.29 cfs
Year	**2007(1)**	(using 1995 Potentiometric surface)							
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)			
		667	250	160	400	365			
Calculation		λ	4.13E+01	r/B	0.057975	G value	0.36	Q	0.52 cfs
Year	**2007(2)**	(using 1995 Potentiometric surface)							
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)			
		356	320	230	400	365			
Calculation		λ	1.45E+02	r/B	0.025808	G value	0.29	Q	0.54 cfs
Year	**2007(3)**	(using 1995 Potentiometric surface)							
Parameters		r (ft)	D (ft)	L' (ft)	L (ft)	t(day)			
		583	180	90	400	365			
Calculation		λ	5.40E+01	r/B	0.067565	G value	0.374	Q	0.39 cfs

Mine facility usage:						1.45 cfs
Lateral recharge						1.19
Total Mine Discharge:						1.19 cfs
Year 2008(1)	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)	
	655	305	215	400	365	
Calculation	λ	4.28E+01 r/B	0.049113 G value	0.35 Q		0.62 cfs
Year 2008(2)	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)	
	743	480	390	400	365	
Calculation	λ	3.33E+01 r/B	0.041365 G value	0.39 Q		1.09 cfs
Year 2008(3)	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)	
	678	208	118	400	365	
Calculation	λ	4.00E+01 r/B	0.068622 G value	0.38 Q		0.46 cfs
Mine facility usage:						2.30 cfs
Lateral recharge						1.45
Total Mine Discharge:						1.33 cfs
Year 2009(1)	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)	
	543	340	250	400	365	
Calculation	λ	6.23E+01 r/B	0.037758 G value	0.35 Q		0.69 cfs
Year 2009(2)	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)	
	230	390	300	400	365	
Calculation	λ	3.47E+02 r/B	0.0146 G value	0.255 Q		0.58 cfs
Year 2009(3)	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)	
	686	160	70	400	365	
Calculation	λ	3.90E+01 r/B	0.090147 G value	0.38 Q		0.35 cfs
Mine facility usage:						1.31 cfs
Lateral recharge						1.45
Total Mine Discharge:						1.77 cfs
Year 2010(1)	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)	
	611	400	310	400	365	
Calculation	λ	4.92E+01 r/B	0.038154 G value	0.35 Q		0.81 cfs
Year 2010(2)	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)	
	790	390	300	400	365	
Calculation	λ	2.94E+01 r/B	0.050147 G value	0.4 Q		0.91 cfs
Year 2010(3)	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)	
	699	203	113	400	365	
Calculation	λ	3.76E+01 r/B	0.072296 G value	0.38 Q		0.45 cfs
Mine facility usage:						2.37 cfs
Lateral recharge						1.48
Total Mine Discharge:						1.28 cfs

Year	**2011(1)**	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	568	410	320	400	365		
Calculation	λ	5.69E+01 r/B		0.03491	G value	0.35 Q	0.83 cfs
Year	**2011(2)**	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	572	348	258	400	365		
Calculation	λ	5.61E+01 r/B		0.039153	G value	0.36 Q	0.73 cfs
Year	**2011(3)**	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	689	60	0	400	365		
Calculation	λ	3.87E+01 r/B		1	G value	0.784 Q	0.27 cfs
Mine facility usage:							1.79 cfs
Lateral recharge							1.48
Total Mine Discharge:							1.52 cfs
Year	**2012(1)**	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	564	450	360	400	365		
Calculation	λ	5.77E+01 r/B		0.032682	G value	0.35 Q	0.92 cfs
Year	**2012(2)**	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	288	340	250	400	365		
Calculation	λ	2.21E+02 r/B		0.020026	G value	0.284 Q	0.56 cfs
Year	**2012(3)**	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	579	0	0	400	365		
Calculation	λ	5.48E+01 r/B		1	G value	0.784 Q	0.00 cfs
Mine facility usage:							1.33 cfs
Lateral recharge							1.48
Total Mine Discharge:							1.63 cfs
Year	**2013(1)**	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	643	525	435	400	365		
Calculation	λ	4.44E+01 r/B		0.033895	G value	0.34 Q	1.04 cfs
Year	**2013(2)**	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	404	255	165	400	365		
Calculation	λ	1.13E+02 r/B		0.034579	G value	0.32 Q	0.47 cfs
Year	**2013(3)**	(using 1995 Potentiometric surface)					
Parameters	r (ft)	D (ft)	L' (ft)	L (ft)	t(day)		
	243	0	0	400	365		
Calculation	λ	3.11E+02 r/B		1	G value	0.545 Q	0.00 cfs
Mine facility usage:							1.01 cfs
Lateral recharge							1.48
Total Mine Discharge:							1.98 cfs

Emery Mine Discharge Prediction

Time	Discharge (cfs)
2006	1.29
2007	1.19
2008	1.33
2009	1.77
2010	1.28
2011	1.52
2012	1.63
2013	1.98
Average	1.50